Governors – Future needs

Future needs and requirement for frequency control functions in the Nordic and Norwegian power system

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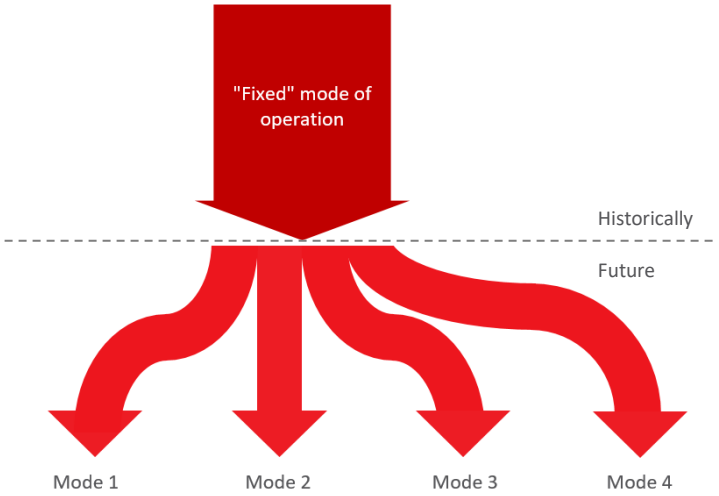
Statnett

Power system needs



Changes is in the power system requires new solutions for provision of reserves and ancillary system services.

Historically, all units in Norway has contributed in the frequency containment process in a more or less fixed configuration, with all units ≥ 10 MVA providing frequency response when operation, only with some operational configurations of droop settings. This does not meet the system requirement for achieving the sufficient frequency quality or quality of supply anymore.

Moving forward Statnett needs better control of active, and inactive, frequency containment reserves for both Nordic and local frequency control. Additionally, there is a goal shared between Statnett, regulatory authorities and reserve providers to utilise markets for procuring reserves. This leads to the necessity of more flexibility and utilization of that flexibility in operation.

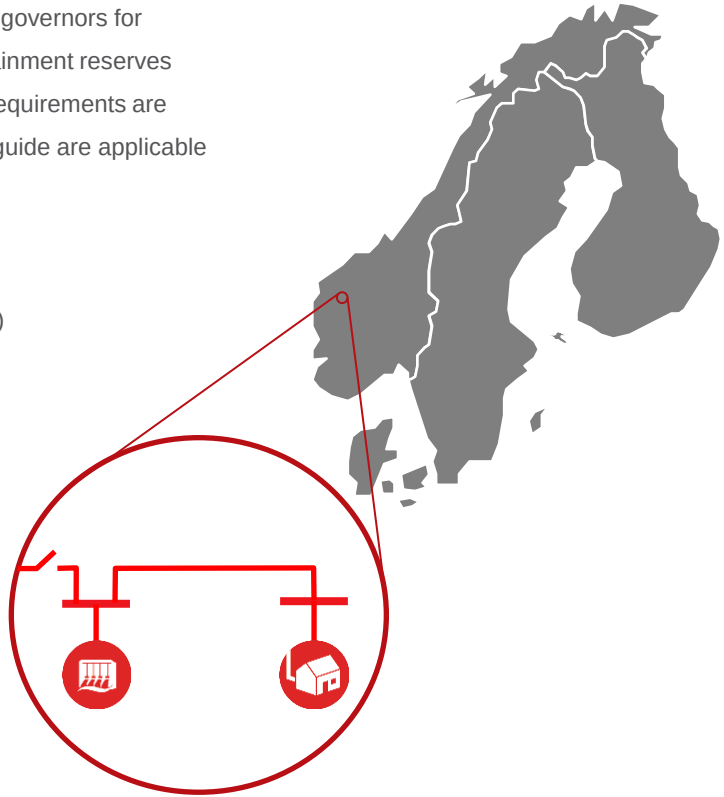
While the new market requirements are not formal, these concepts are final. The future of FCR-provision will require more flexibility.

Local and "global" needs

This guide highlights the functions and settings that must or can be implemented in governors for fulfilling the grid code and the upcoming requirements for providing frequency containment reserves (FCR/frekvensregulering/primærreserve) in the Nordic power system. The market requirements are being revised and formalized during 2021/2022, but the functions described in this guide are applicable for both the revised and the present requirements.

- Mandatory grid code [1] requirements for new and refurbished units aiming to ensure security of supply in island mode (FCR-I) and for emergency supplement of frequency controlled reserves (LFSM).

- Non-mandatory market requirements for participation in FCR-N and FCR–D markets [2]
  - Necessary functions for achieving prequalification
  - Optional functions to achieve increased flexibility and/or abilities



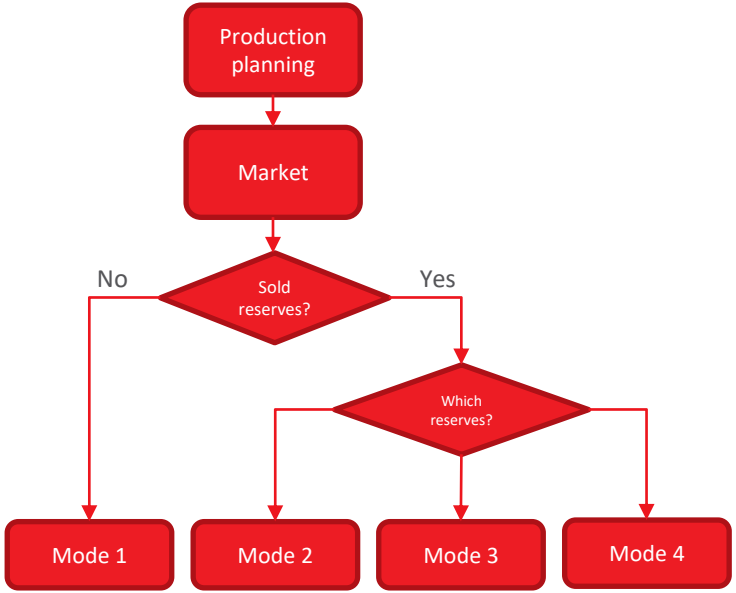
Note the national grid code and market requirements are the governing documents and that this document does not replace those, and in case of mismatches the referred to documents are the legally binding ones.

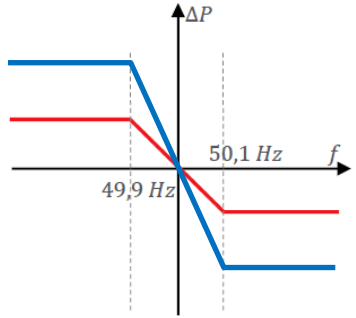
New operational use

The market obligations and/or required deliveries determines how the functionality is used in operation.

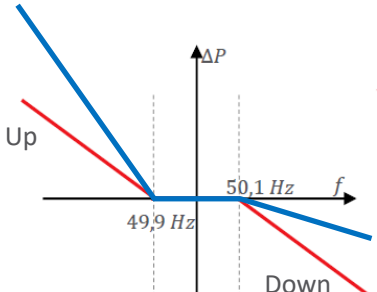
The functionality presented in this document is based on the planned transition from mandatory delivery of FCR (grunnleveranse) in combination with market procurements, to solely market based procurement of FCR-N and -D.

The foreseen impact of these changes are a need for in-operation configuration of more parameters/settings than what is presently the normal, which in practice only includes droop for providing more or less FCR-N and FCR-D. The new needs include deadband, saturation, island mode detection and possibly dynamic response configuration (by configuring regulator parameters, e.g. PID)





FCR-N



FCR-D

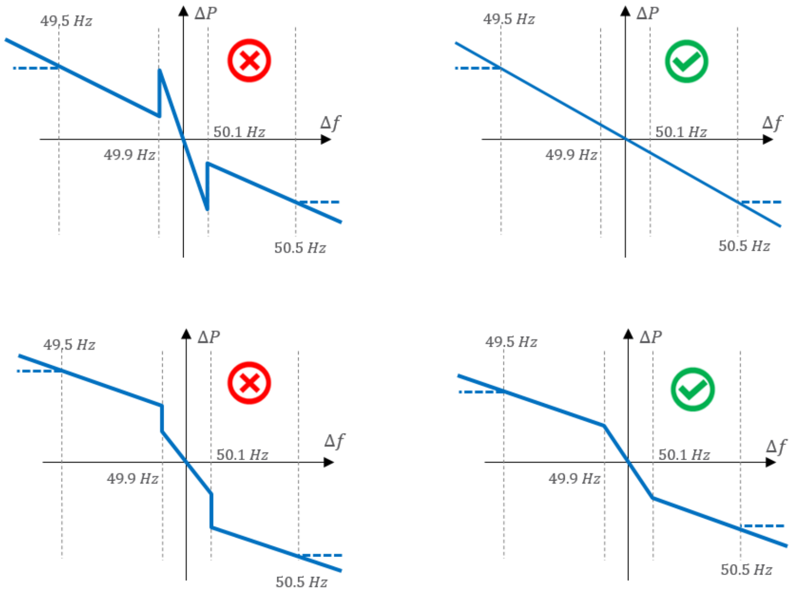
Frequency Containment Reserves

FCR, Frequency containment reserves is a proportionally activated reserve, activating a power response upwards or downwards depending on the bid and continuous frequency variations.

- FCR-N is activated proportionally between 49,9 and 50,1 Hz, with the sold capacity provided upwards and downwards at under and over frequency respectively, referred to 50 Hz.
- FCR-D Up is activated from 49,9 and proportionally to full activation of the sold capacity at 49,5 Hz
- FCR-D Down is activated from 50,1 and proportionally to full activation of the sold capacity at 50,5 Hz
- Droop settings decides the proportional FCR-response at varying frequency

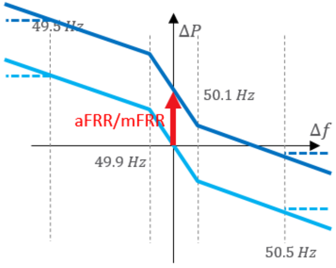
Figures – Top left: FCR-N stationary activation at two different droops, bottom left: FCR-D Up and Down stationary activation at two different droops

Simulataneous delivery of reserves



Simultaneous delivery of reserves require ability to maintain other activated reserves, whilst having capacity for activate other sold reserves.

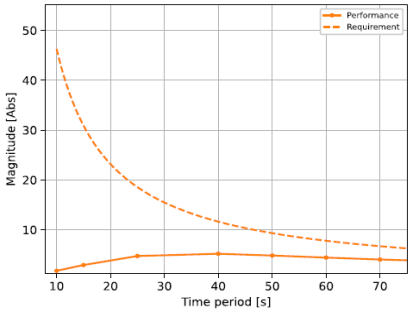
For FCR this means that the droop must be continuous, and not "jump" so that an large instantaneous control signal is not sent

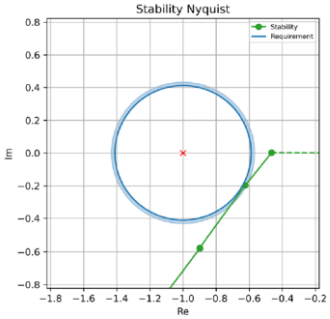


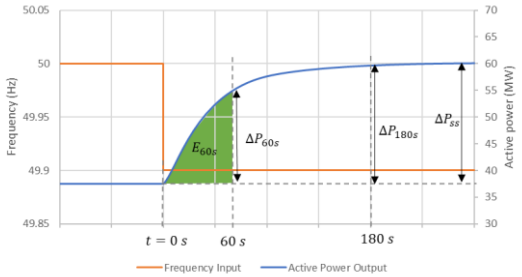
Figures - Right: combinations of droop over frequency range, left: illustration of effect of activation of aFRR or mFRR, automatic and manual Frequency Restoration Reserves.

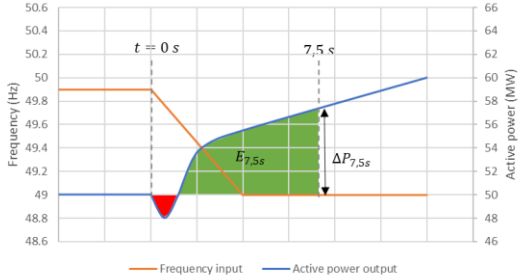
FCR Dynamic properties

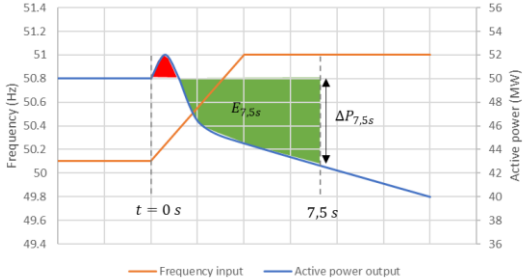
- There are different requirements for FCR-N and –D response due to different power system needs
- FCR-N and FCR-D may be provided with:
  - Same regulator parameters for FCR-N, FCR-D Up and FCR-D Down. Will be sufficient when the inherent properties of the unit is good, e.g. low penstock time constant
  - Different regulator parameters for different reserves, e.g. different proportional gains in a PID-regulator. May be relevant for units with less good properties, or where a provider don't want to overperform for one or the other reserve dynamic performance, i.e. respond faster than necessary
  - Different regulator parameters during transient and stationary frequency, i.e. enabling short duration higher performance, with switching to higher stability







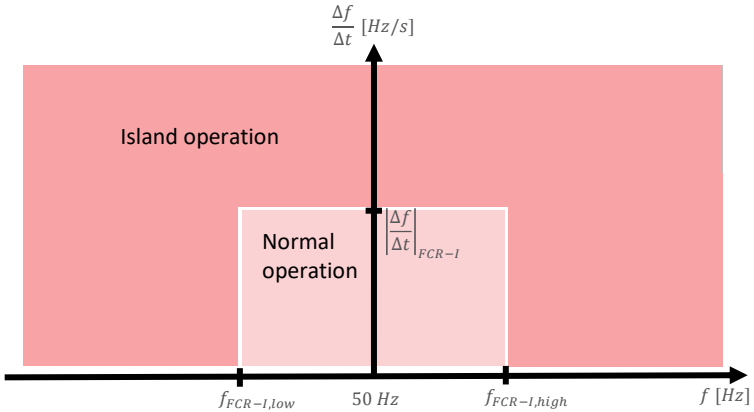




Figures – Bottom left: FCR-N closed loop response requirement, bottom middle: FCR-N and FCR-D stability requirement, top right: FCR-N Dynamic response requirement, middle right: FCR-D Up Dynamic requirement, bottom right: FCR-D own Dynamic requirement.

FCR-I – Island mode detection and control

- Automatic parameter switching of
  - Droop
  - Deadband
  - Regulator parameters to island mode stability
- Blockage of new commands from AGC, LFC-control, etc.
- Remote manual switch off
- Deactivation signal to voltage controller for disabling of PSS



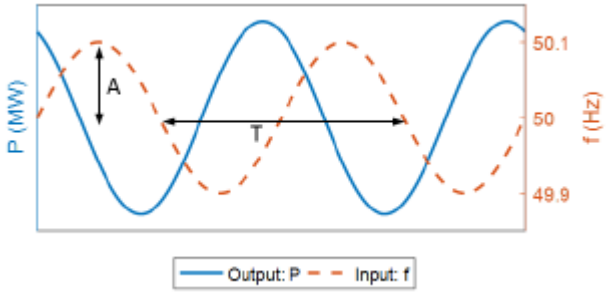
Value	Term	Settings	Default setting
Activation threshold – low	$f_{FCR-I,low}$	$45 - 50\ Hz$	$49{,}0\ Hz$
Activation threshold – high	$f_{FCR-I,high}$	$50 - 55\ Hz$	$51{,}0\ Hz$
Activation threshold – ROCOF	$\left\|\frac{\Delta f}{\Delta t_{FCR-I}}\right\|$	$0 - 10\ s$	$1\ Hz/s$
Delay	t_{FCR-I}	$0 - 120\ s$	$0\ s$
Droop	e_p	$2 - 12\%$	4%
Voltage regulator	Power system stabilizer	On/off	$None$

Figures/tables – left: illustration of activation thresholds for FCR-I, right: settings for FCR-I

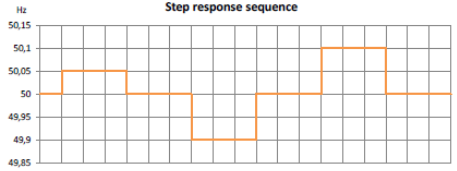
Internal test functions

- Compliance of FCR and grid code requirements is shown by performing tests using applied frequency signals to invoke a active power response

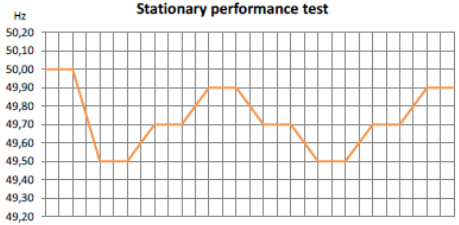
- Frequency test signals include
  - Steps
  - Ramps with varying slope (ranging from 2 mHz/s to 0.24 Hz/s)
  - Sines with varying period time (ranging from 10 s to 70 s)



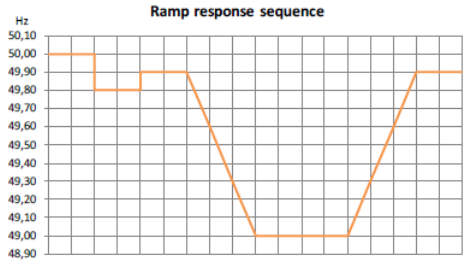
50.00 Hz → 50.05 Hz → 50.00 Hz → 49.90 Hz →50.00 → 50.10 Hz → 50.00 Hz



50.00 Hz → 49.50 Hz → 49.70 Hz → 49.90 Hz → 49.70 Hz → 49.50 Hz → 49.70 Hz → 49.90 Hz



50.00 Hz → 49.80 Hz → 49.90 Hz → 49.00 Hz → 49.90 Hz

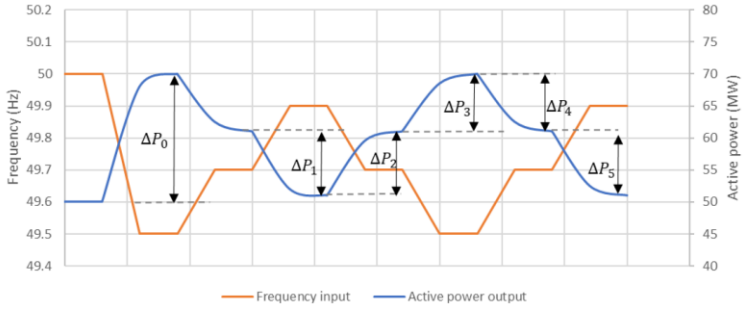


Figures – Bottom left: Applied sine signal and response, top right: FCR-N stationary performance test, middle right: FCR-D stationary performance and linearity test , bottom right: FCR-D Up performance test

Internal measurements

- Testing:
  - Applied frequency, measured grid frequency and active power (and if applicable; parameter switches)
  - Saved appropriately to be sent to TSO
- During operation:
  - Logging of measurements
  - Frequency and active power
  - Can be saved within the governor or signalled to external equipment
- Shall be measured with sufficient resolution and accuracy.

  Sampling rate of at least 5 Hz for FCR-N and 10 Hz for FCR-D



Measured quantity	Category	Rated power of the resource being measured	Accuracy	Resolution
Active power	1	< 2 MW	± 5%	0,01 MW or 0,025%
	2	2 – 10 MW	±1%	
	3	> 10 MW	± 0,5 %	
Grid frequency	N/A	N/A	± 10 mHz	1 mHz
Applied frequency	N/A	N/A	±10 mHz	1 mHz

Figures/tables – top right: Applied ramp signal and active power response for FCR-D Up performance test, bottom right: requirements on accuracy and resolution.

Function		No (grid code)	Only FCR-N	Only FCR-D Up	Only FCR-D Down	FCR-D Up and FCR-D Down	FCR-N, FCR-D Up and FCR-D Down	All
Droop settings		2-12 %	By provider choice	By provider choice	By provider choice	By provider choice	By provider choice	**At least 2 – 12 %**
Regulator tuning		X	X	X	X	X	X	**X**
Dead band (settings)		X (0,5 Hz)		X ($-0{,}1\ Hz$ / $+\ 0{,}5\ Hz$)	X ($-0{,}5\ Hz$ / $+\ 0{,}1\ Hz$)	X ($-0{,}1\ Hz$ / $+\ 0{,}1\ Hz$)		**X (0 – 0.5 Hz and asymetrical)**
Saturation			X ($\pm$0,1 Hz)					**X**
FCR-I		X	X	X	X	X	X	**X**
Internal test functions		(X)	(X)	(X)	(X)	(X)	(X)	**(X) External equipment possible**
Internal measurements		(X)	(X)	(X)	(X)	(X)	(X)	**(X) External equipment possible**
Logging of data		(X)	(X)	(X)	(X)	(X)	(X)	**(X) External equipment possible**
Special considerations for simultaneous delivery of FCR-N and FCR-D Up and Down (Possibilities but not exhaustive)	Parallel controllers (multiple modes of droop and regulator settings)	(X) Maybe if separate controller is used for LFSM control		(X) Maybe for high performance/high stability	(X) Maybe for high performance/high stability	(X) Maybe for high performance/high stability	(X) Maybe for either high performance/high stability and/or due to different parameter sets (PID, droop, etc.) between FCR-N and –D	**(X) Depending on design**
	Switching of regulator setting (or other type of regulator)			(X) Maybe for high performance/high stability	(X) Maybe for high performance/high stability	(X) Maybe for high performance/high stability	(X) Maybe for either high performance/high stability and/or due to different parameter sets between FCR-N and -D	**(X) Depending on design**
	Parallel droop feedback-loops (i.e. simplified parallel controller)	(X) Maybe a separate feedback for LFSM control					(X) Maybe if different droop settings is used between FCR-N and -D	**(X) Depending on design**
	Other	(X)	(X)	(X)	(X)	(X)	(X)	**(X)**

'X' indicates yes, and '(X)' indicates optional/possible

References

[1] Nasjonal Veileder for Funksjonskrav, 2020 (link)

[2] Technical Requirements for Frequency Containment Reserves (FCR) in the Nordic synchronous area – for pilot phase (link)

[3] Supporting Document on Technical Requirements for Frequency Containment Reserves (FCR) in the Nordic synchronous area – for pilot phase, 2021 (link)